Tensors, BICEP2, prior dependence, and dust

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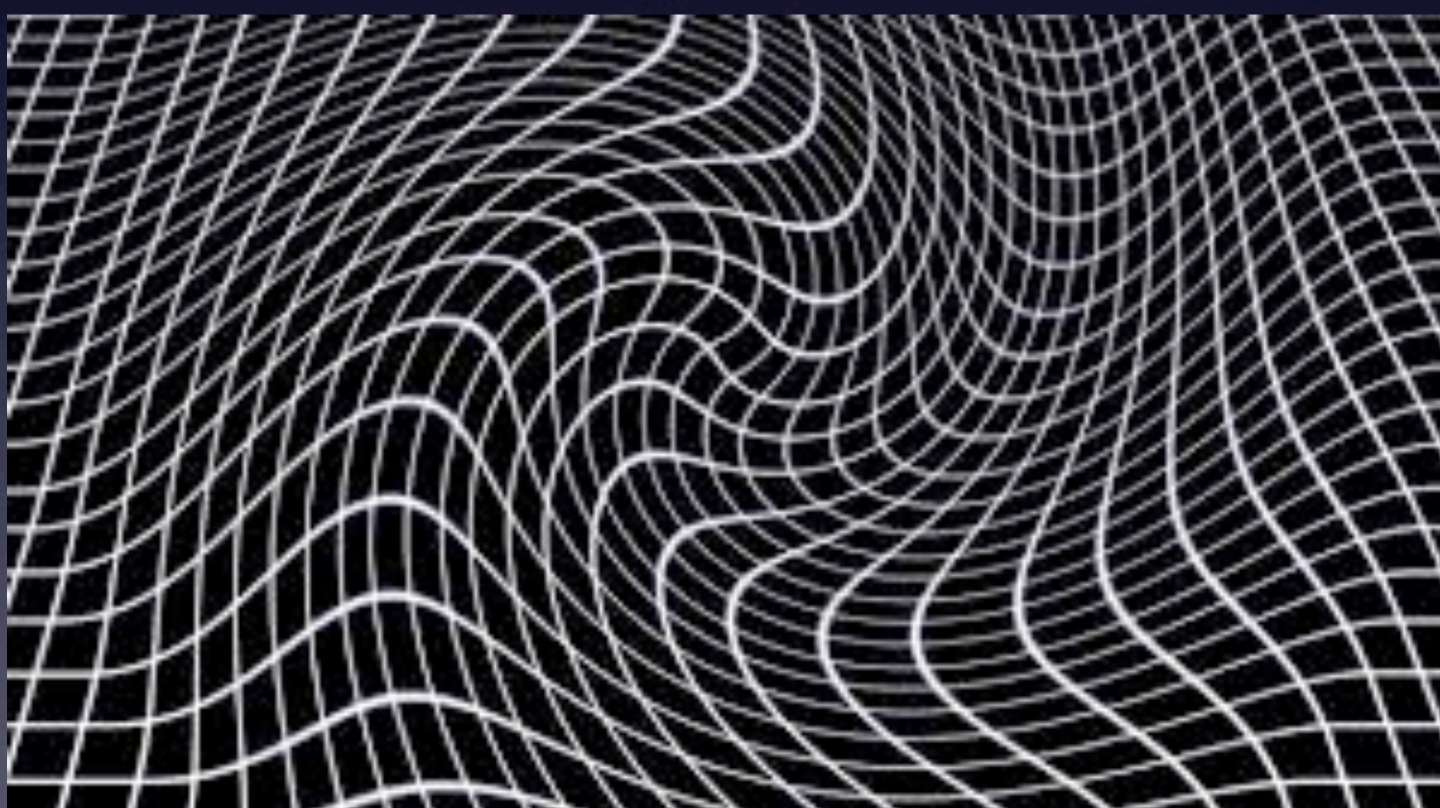
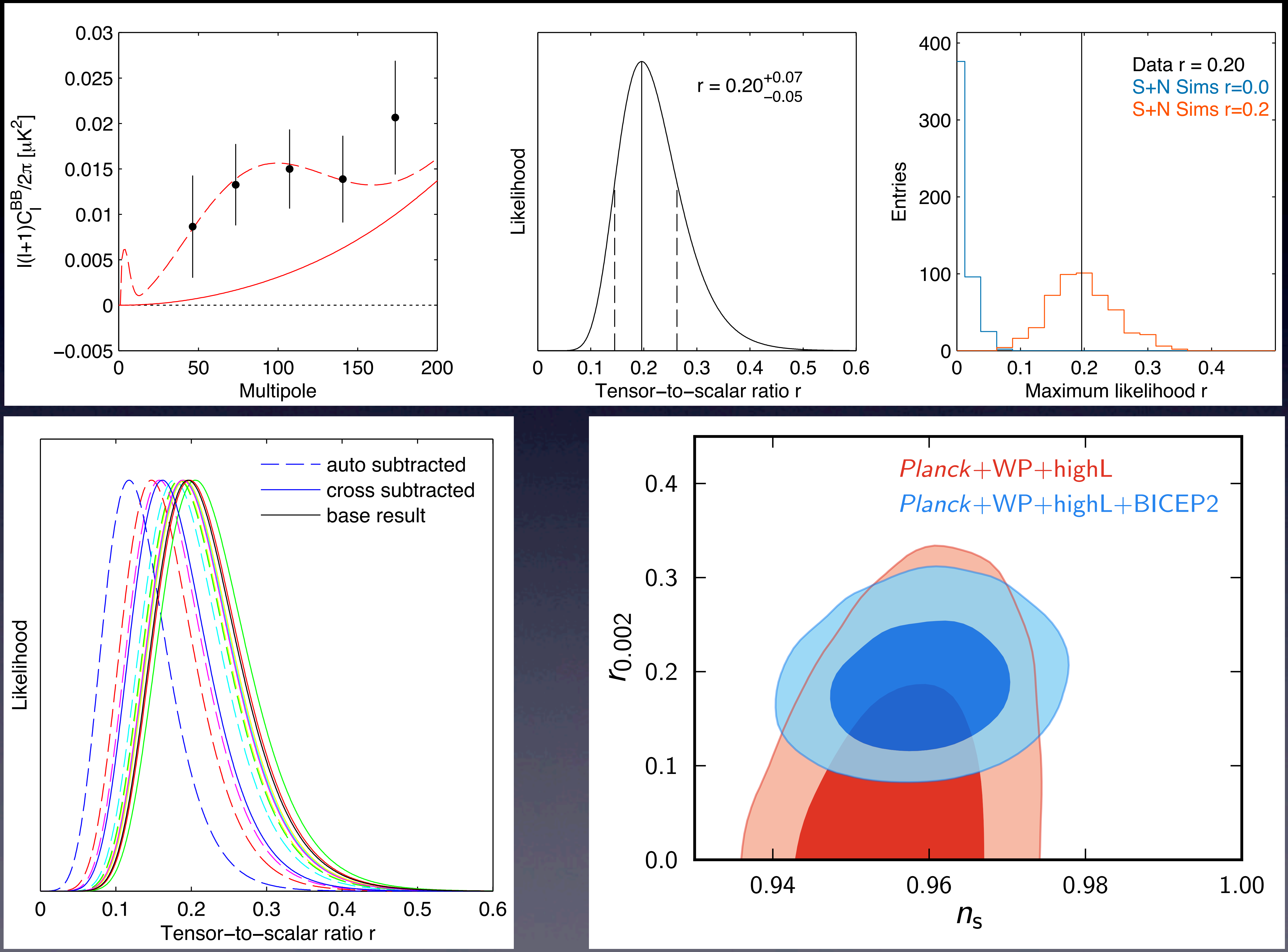


Marina Cortês, Andrew Liddle and David Parkinson: arXiv:1409.6530

[and also arXiv:1107.2673 for pre Planck/BICEP analysis]

BICEP2



l(l+1)C_l^BB/2π [μK²]
Multipole
Likelihood
r = 0.20 +0.07 −0.05
Tensor−to−scalar ratio r
Entries
Data r = 0.20
S+N Sims r=0.0
S+N Sims r=0.2
Maximum likelihood r
auto subtracted
cross subtracted
base result
Likelihood
Tensor−to−scalar ratio r
Planck+WP+highL
Planck+WP+highL+BICEP2
r_0.002
n_s

Principled approach to tensor detection

We advocate that analyses seeking to detect tensors from data should adopt the following principles:

- Constraints should be imposed directly on the tensor amplitude A_T, rather than on the tensor-to-scalar ratio r.
- The prior distribution for the amplitude A_T must be chosen with care, and should not select out a preferred observed scale.
- The amplitude should be constrained at an optimized `pivot' scale for the chosen dataset combination.

$$\begin{aligned} A_{\rm S}(k) &= A_{\rm S}(k_0) k^{n_{\rm S}-1}\,, \\ A_{\rm T}(k) &= A_{\rm T}(k_0) k^{n_{\rm T}}\,, \end{aligned}$$

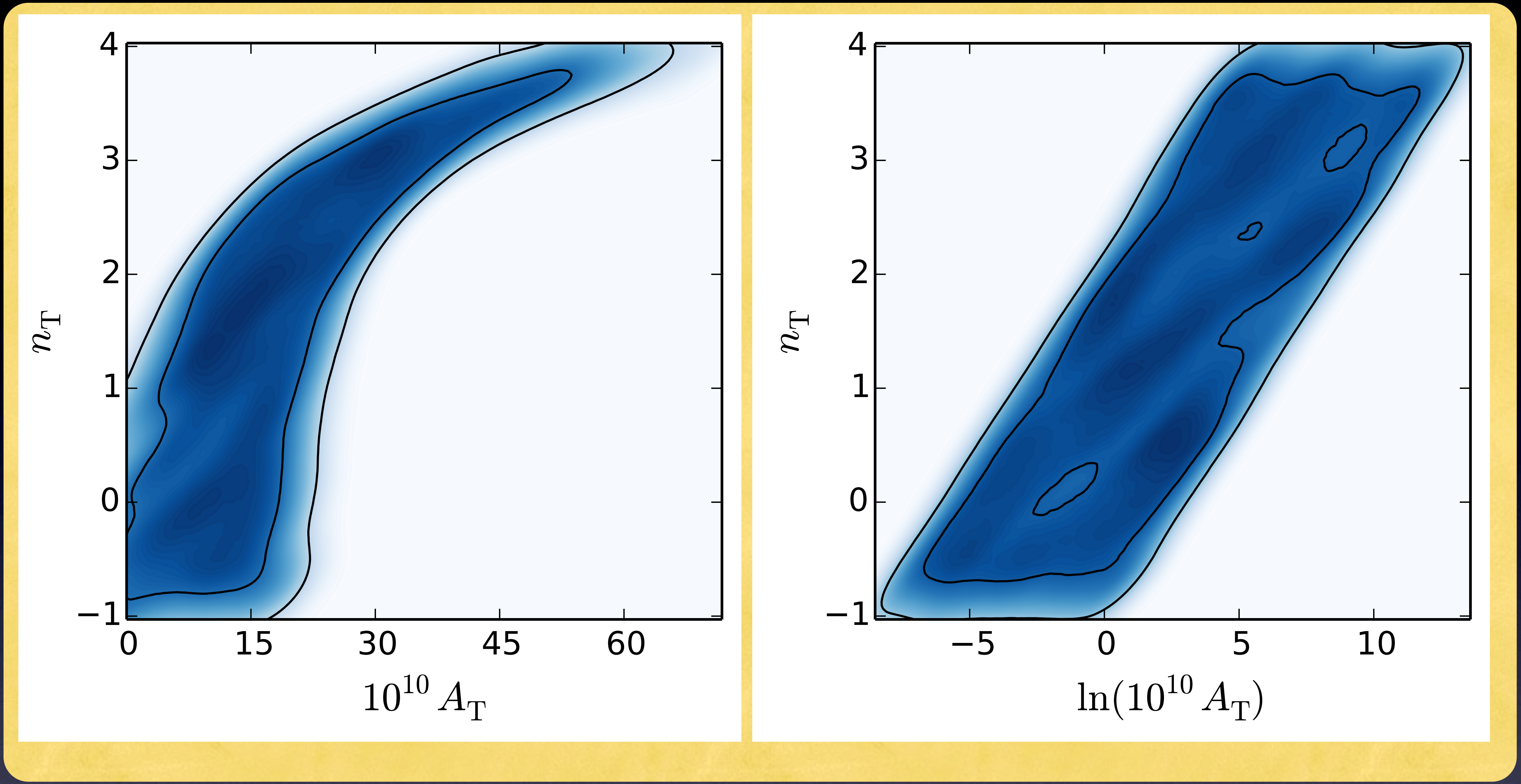
What should the prior on A_T be?

Analyses to date have typically imposed a uniform prior on the tensor-to-scalar ratio *r*, most commonly at the CosmoMC pivot scale 0.05 Mpc^{-1}.

As the BICEP2 signal is much stronger than expected, the tensor spectral index n_T is found to be strongly positive.

Priors are for you to choose, but need to be chosen carefully.
Some options:

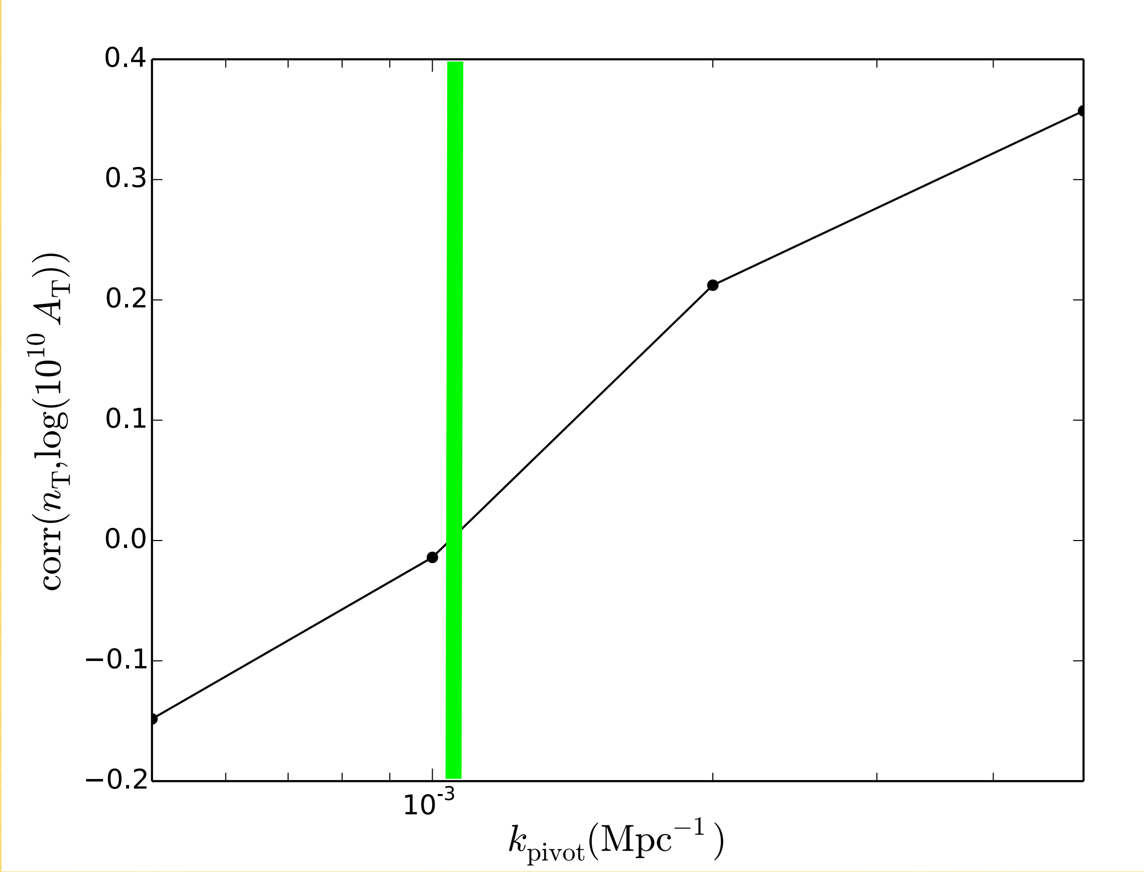
- Linear on A_T (or *r*): But this selects a special scale; a prior linear at one scale becomes strongly non-linear on another.
- Logarithmic on A_T (or *r*): Expresses ignorance of the order-of-magnitude of the amplitude. Pivot-scale-independent for power-law spectra (apart from boundary effects).
- Superposition of the above: A plausible way of including knowledge that $n_s - 1 = -6\epsilon + 2\eta$ is non-zero.



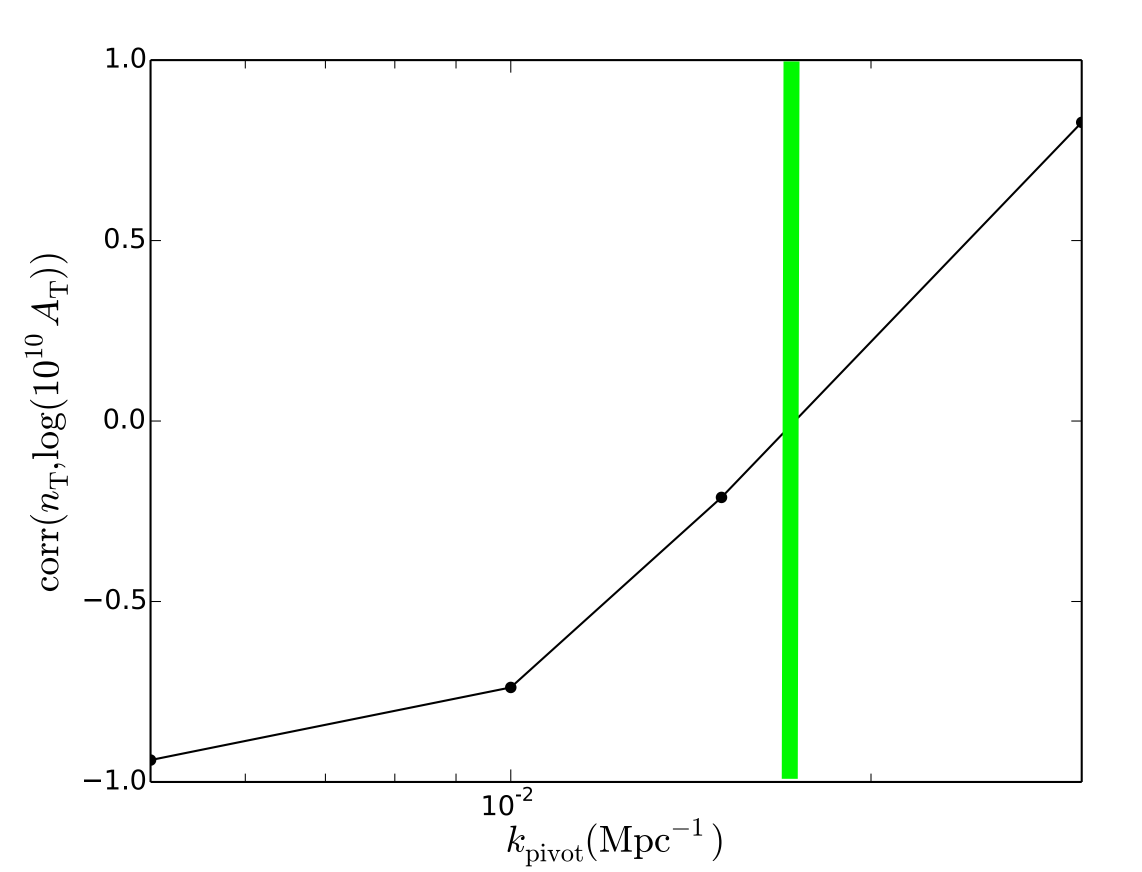
If we assume uniform priors at a pivot scale 0.001 Mpc^{-1}, this is what they look like when transformed to a pivot of 0.015 Mpc^{-1}.

Which pivot?

The pivot scale for a given dataset combination can be found by analysing the correlation coefficient of A_{T} and n_{T}. The scale where it vanishes is the one where the determination of the amplitude becomes independent of the slope.

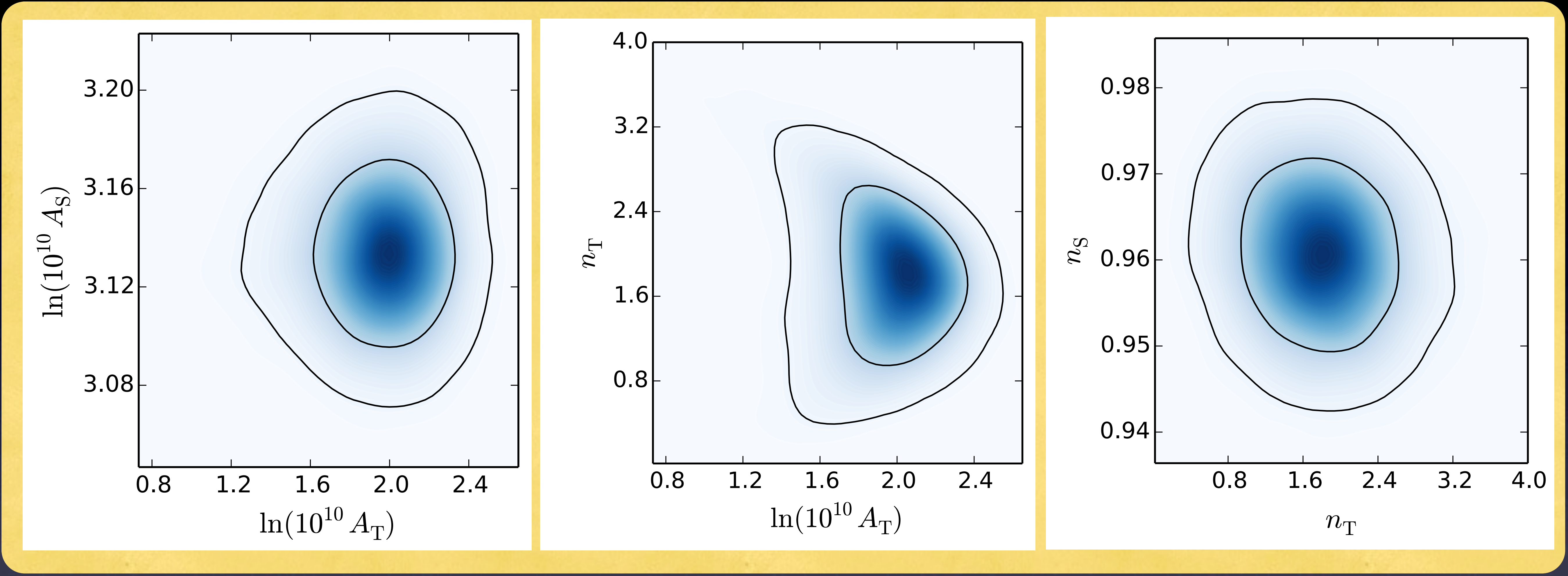


Planck (2013) + WP
$k_{\mathrm{pivot}} \approx 0.001\ \mathrm{Mpc}^{-1}$



Planck (2013) + WP + BICEP2
$k_{\mathrm{pivot}} \approx 0.015\ \mathrm{Mpc}^{-1}$

Analysis 1: No dust



Note that the spectral index is strongly detected as positive, $n_T = 1.8 \pm 0.6$ (as already found by other authors, eg Gerbino et al, Chang and Xu).

Our central value corresponds to $\boldsymbol{r = 0.32}$, higher than BICEP2's value only because n_T is typically positive and it is being quoted on a shorter scale.

Analysis 2: With dust

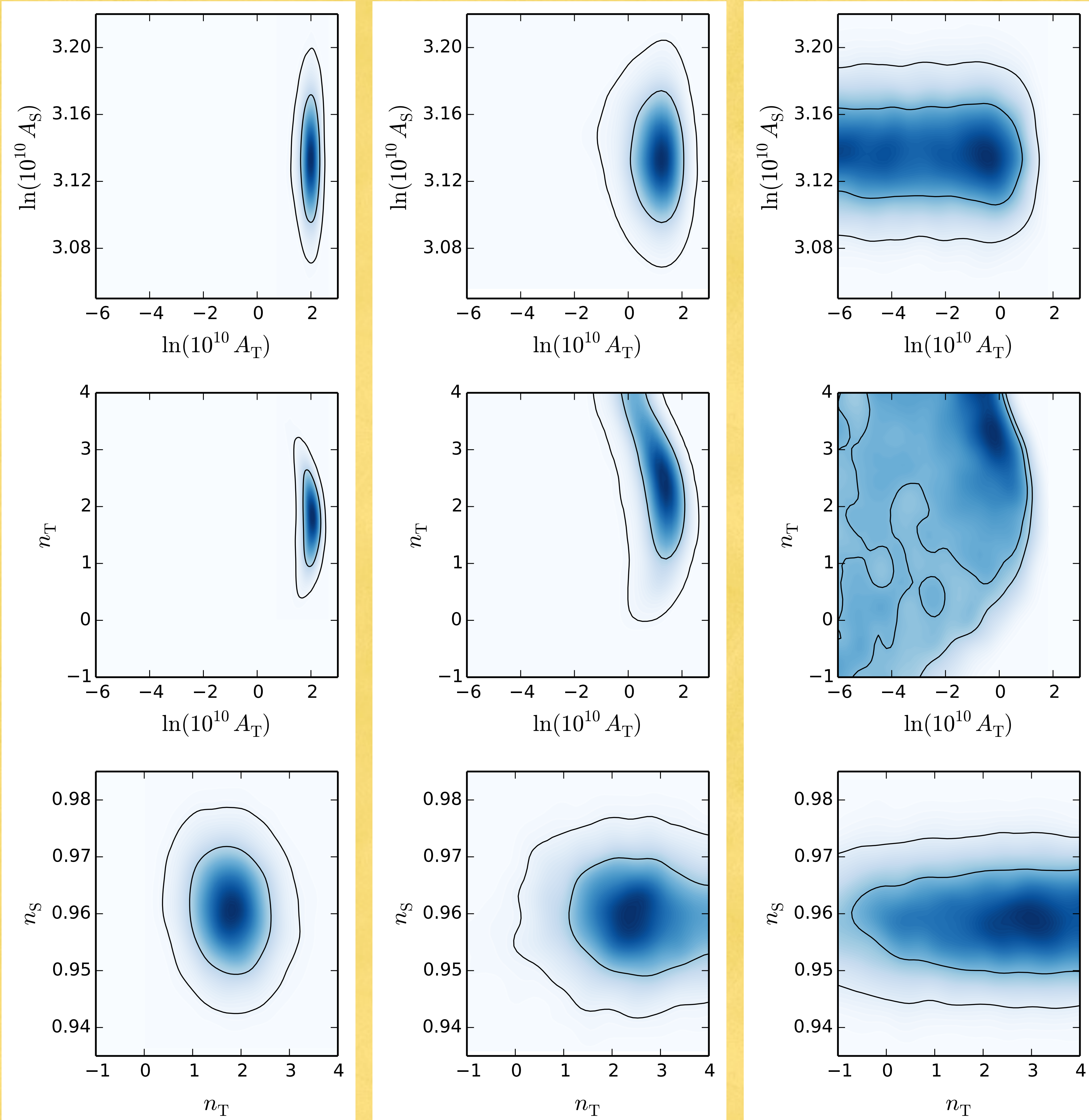
It is now believed that some or all of the BICEP2 B-mode signal is due to polarized dust emission. Mortonson & Seljak showed that a generic power-law dust spectrum could adequately explain the B-mode spectrum and *Planck* (Adam et al) showed that the required amplitude is plausible from extrapolation from 353 GHz.

Rather than repeat the Mortonson-Seljak analysis, we envisage that future measurements have fixed the dust amplitude to high precision and investigate how it would alter the analysis.

$$\Delta^2_{BB,dust}\,(\ell = 100) = 0.005\ \mu K^2 \text{ (optimistic)}$$

$$\text{and } 0.010\ \mu K^2 \text{ (pessimistic)}$$

We keenly await news from the joint *Planck*/BICEP2 analysis.



(a) $\Delta^2_{BB,\mathrm{dust}} = 0$ **No dust**

(b) $\Delta^2_{BB,\mathrm{dust}} = 0.005\,\mu\mathrm{K}^2$ **Optimistic**

(c) $\Delta^2_{BB,\mathrm{dust}} = 0.010\,\mu\mathrm{K}^2$ **Pessimistic**

The `optimistic' scenario (just) preserves a two-sigma detection of tensors, but still with $n_T>0$ at the same confidence.

The `pessimistic' scenario completely loses the detection.

Conclusions

- We advocate a principled approach to setting constraints on tensor modes. Its main features are
  - Impose constraints on the tensor amplitude itself.
  - Careful choice of prior distribution
  - Identification of optimal pivot scale of observations.
- If the BICEP2 signal were completely primordial, it is incompatible with the standard inflationary prediction $n_T<0$.
- Dust can readily explain some or all of the BICEP2 signal.
- If the dust contribution is strong enough to allow $n_T<0$, the BICEP2 detection is no longer statistically significant.

Planck constraints on inflation are correct.

BICEP2 has detected primordial tensors.

Standard inflation ($n_T<0$) is viable.

You can have two corners of this triangle, but not all three!